

Developing a Model Component

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The Spaceport Command and Control System (SCCS) Simulation Computer Software Configuration Item (CSCI) is responsible for providing simulations to support test and verification of SCCS hardware and software. The Universal Coolant Transporter System (UCTS) was a Space Shuttle Orbiter support piece of the Ground Servicing Equipment (GSE). The initial purpose of the UCTS was to provide two support services to the Space Shuttle Orbiter immediately after landing at the Shuttle Landing Facility. The UCTS is designed with the capability of servicing future space vehicles; including all Space Station Requirements necessary for the MPLM Modules. The Simulation uses GSE Models to stand in for the actual systems to support testing of SCCS systems during their development. As an intern at Kennedy Space Center (KSC), my assignment was to develop a model component for the UCTS. I was given a fluid component (dryer) to model in Simulink. I completed training for UNIX and Simulink. The dryer is a Catch All replaceable core type filter-dryer. The filter-dryer provides maximum protection for the thermostatic expansion valve and solenoid valve from dirt that may be in the system. The filter-dryer also protects the valves from freezing up. I researched fluid dynamics to understand the function of my component. The filter-dryer was modeled by determining affects it has on the pressure and velocity of the system. I used Bernoulli's Equation to calculate the pressure and velocity differential through the dryer. I created my filter-dryer model in Simulink and wrote the test script to test the component. I completed component testing and captured test data. The finalized model was sent for peer review for any improvements. I participated in Simulation meetings and was involved in the subsystem design process and team collaborations. I gained valuable work experience and insight into a career path as an engineer.

Nomenclature

$z1$	= Elevation 1
$z2$	= Elevation 2
$p1$	= Input Pressure
$p2$	= Output Pressure
$v1$	= Input Velocity
$v2$	= Output Velocity
g	= Gravity Constant
pg	= Density Constant * Gravity Constant
hl	= Head Loss
k	= K Factor
f	= Friction Factor
l	= Length
d	= Outlet Diameter
Re	= Reynolds Number
u	= Dynamic Viscosity
v	= Outlet Velocity
p	= Density

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I. Introduction

A. NASA

Since the establishment in 1958, NASA has accomplished great scientific and technological advances. NASA has faced many challenges in the recent years with the end of the space shuttle program and the cancellation of the Constellation program. The conclusion of these programs has opened new platforms of exploration, technology development, and scientific research. NASA is designing and building the technology to send humans to explore the solar system. NASA is developing the Space Launch System (SLS) for human exploration beyond Earth's orbit and building the Orion Multi-Purpose Crew Vehicle to take astronauts on multi day missions.³ NASA is continuing to use the International Space Station (ISS) for scientific research and exploration technologies. Commercial companies are providing cargo and crew flights to the ISS. NASA is working toward building aircrafts that are safer, more fuel efficient, quieter, and environmentally responsible. NASA is seeking new knowledge and understanding of Earth and the universe. NASA has a significant future and remains a leading force in scientific research and aerospace exploration.

B. Space Launch System

The SLS Program is developing a launch solution for delivering humans (crewed) and cargo (un-crewed) payloads to space. The crewed solution is composed of the SLS Program Launch Vehicle (LV) and the Spacecraft (SC). The current Spacecraft is Orion.³ The crew and electronics generate unwanted heat within the SC during pre-launch processing. The SC also generates unwanted heat during ground operations (testing, pre-launch, and launch up to T-0 activities) from various flight subsystems which flight heat rejection systems cannot reject on the ground. The Ground Cooling System (GCS) is used to reject this heat.³

The GCS is Ground Support Equipment (GSE) that loads and circulates coolant through the Flight-to-Ground Heat Exchanger to reject heat. The GCS operates during ground operations, when the Spacecraft is powered, and during GCS maintenance operations. The GCS circulates coolant through spacecraft's ground heat exchanger. It maintains required temperature, pressure, and flow rate at flight interface.³ The GCS verifies fluid is below maximum particulate content and within purity requirements. The GCS also provides testing, evacuation, fill, and recovery capability. The flight propylene glycol/water loop carries heat generated within the spacecraft to the flight-ground heat exchanger. The GCS removes this heat with HFC-134a refrigerant through the ground side of this heat exchanger. A significant portion of the GCS functionality located at the Multi-Payload Processing Facility (MPPF) and the Vehicle Assembly Building (VAB) is based on the legacy Space Shuttle Program (SSP) Universal Coolant Transporter System (UCTS).³

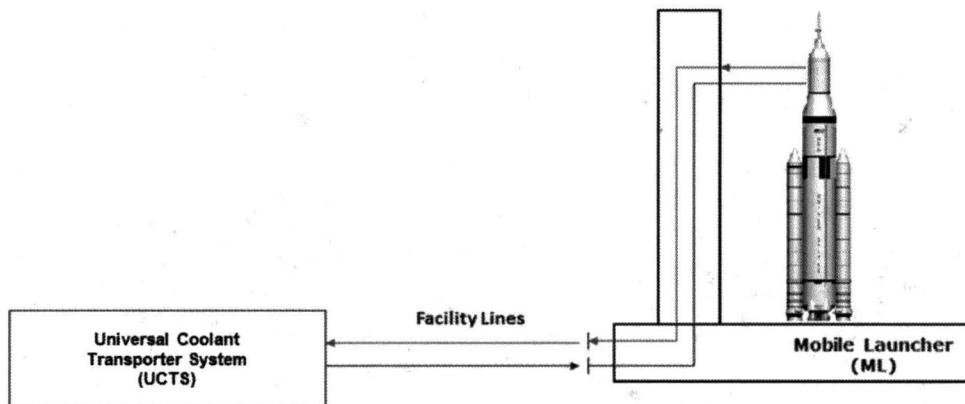


Figure 1. VAB GCS Architecture.

II. Detail

A. UCTS

The UCTS is a support piece of GSE. The initial purpose was to provide two support services to the Space Shuttle Orbiter immediately after landing. The system was designed to be adaptable for future coolant service applications beyond the Space Shuttle Orbiter. The UCTS consists of a flatbed tractor-trailer assembly with the servicing GSE resting in an environmentally maintained enclosure mounted on it. The UCTS is capable of handling a wide range of heat loads by placing two properly sized refrigeration systems in series. Each is false loaded with electric heaters in a secondary loop, at a constant flow rate, maintaining a constant system load. The secondary loop is required to convert the variable return heat load into a constant heat load to the refrigeration system. This simple and reliable refrigeration system designed for one set point eliminates the need for complex subsystems.¹

The UCTS includes a flat deck trailer, a hydraulically operated boom, an environmental maintained enclosure, a coolant fluid distribution system (FDS), the coolant GSE, and two electrical generators. The hydraulically operated boom supports the FDS from the UCTS to the umbilical carrier assembly. The environmental maintained enclosure is designed to maintain a conditioned – protected environment for the coolant GSE and the system operators. The enclosure allows for the electrical components to be of a non-hazardous class rating. The generators have the ability to be operated both locally at the generator and remotely from the UCTS programmable logic controller (PLC) control station. The FDS consist of an entirely welded tubing system that is used to transport the coolant media refrigerant R-124 from the GSE. The FDS is installed on the hydraulically operated boom and utilizes four flex hose assemblies to get to and from the boom. The FDS has at the tip of the boom coolant supply and return temperature transducers, low point drain valves and tubing, and supply and return isolation valves. The hydraulically operated boom FDS has a free floating bulkhead plate designed to accommodate thermal expansion and contraction. The coolant GSE consists of four subsystems that are packaged in a single open cabinet structure. The circulation control subsystem contains the temperature and flow control valves, filters, temperature, pressure, and flow transducers that are used to maintain the UCTS primary R-124 loop. The reservoir pump subsystem contains a 40-gallon reservoir that is used as an accumulator to maintain a constant head pressure on the UCTS pumps. The heater subsystem contains two heaters that are used to false load each secondary R-124 loop. Each heater contains a backup over temperature protection thermocouple located on the heater element. The refrigeration subsystem contains a refrigerant R-404 positive displacement compressor, a receiver, chiller barrel, expansion valve, and a suction heat exchanger/accumulator. The UCTS coolant instrumentation primarily consists of electrical transducers that are monitored on a PLC at the UCTS work station.¹

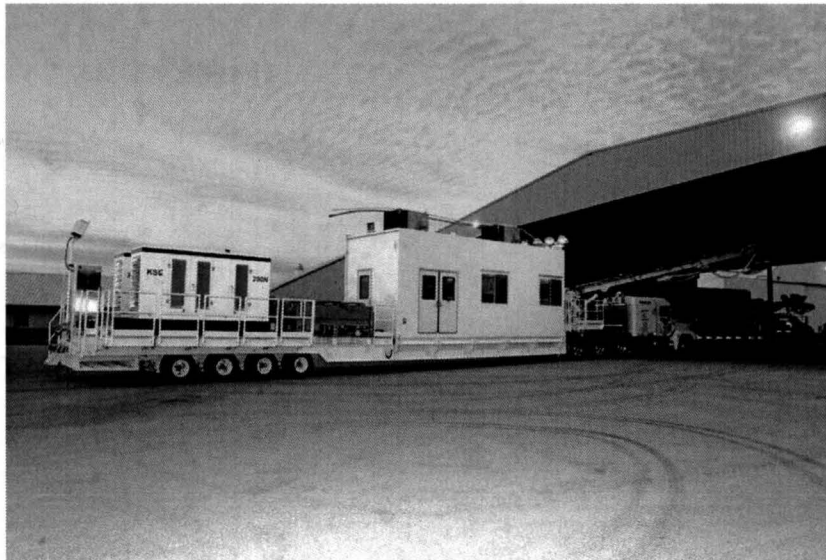


Figure 2. Universal Coolant Transporter System.

B. Modeling

The assignment I was given as an intern at the KSC was to simulate a fluid component for the UCTS. The Spaceport Command and Control System (SCCS) Simulation Computer Software Configuration Item (CSCI) is responsible for providing simulations to support test and verification of SCCS hardware and software. The Simulation uses GSE Models to stand in for the actual systems to support testing of SCCS systems during their development. I spent the first two weeks with my mentor configuring my workstation environment and completing online courses for UNIX and Simulink. I researched fluid dynamics through books and websites. I read documents to familiarize myself with the simulation requirements. The type of fluid component I was given to model was a replaceable core type filter-dryer. I researched the exact filter I was modeling. The filter-dryer enhances shell filtration ability and provides protection and flexibility. The dryer provides maximum water capacity, excellent acid removal characteristics, and the ability to remove products of oil decomposition. Once the programs were ready for use on my computer I was ready to start modeling.²

Before I started using Simulink, I brainstormed ideas for the effects a filter dryer might have on a system such as pressure and velocity differentials. I organized my thoughts on how to mathematically model the component. I found Bernoulli's equation to calculate the velocity and pressure differential. I searched through other components for styling guidance. I wrote the requirements for the dryer in Matlab. The model will compute the pressure differential through the dryer using Bernoulli's equation based on the fluid flow and frictional losses, calculate the head loss based on geometry and physical properties of the fluid, and only allow flow in one direction. I used Simulink to make my equations within a subsystem. I completed my model with a mask of the subsystem. Bernoulli's equation:

$$z_1 + (p_1 / \rho g) + ((v_1^2) / 2g) = z_2 + (p_2 / \rho g) + ((v_2^2) / 2g) + h_l$$

$$h_l = (k * (v^2)) / 2g$$

$$k = f * (l / d)$$

$$f = (64 / Re) = (64 * \mu) / (128 * d * v * \rho)$$

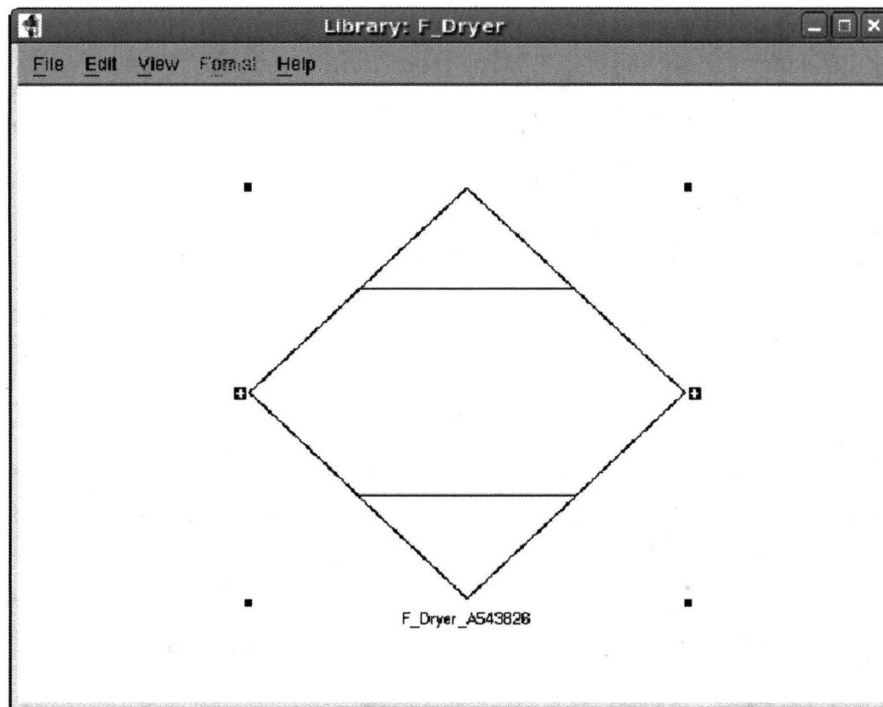


Figure 3. Mask to Dryer Subsystem.

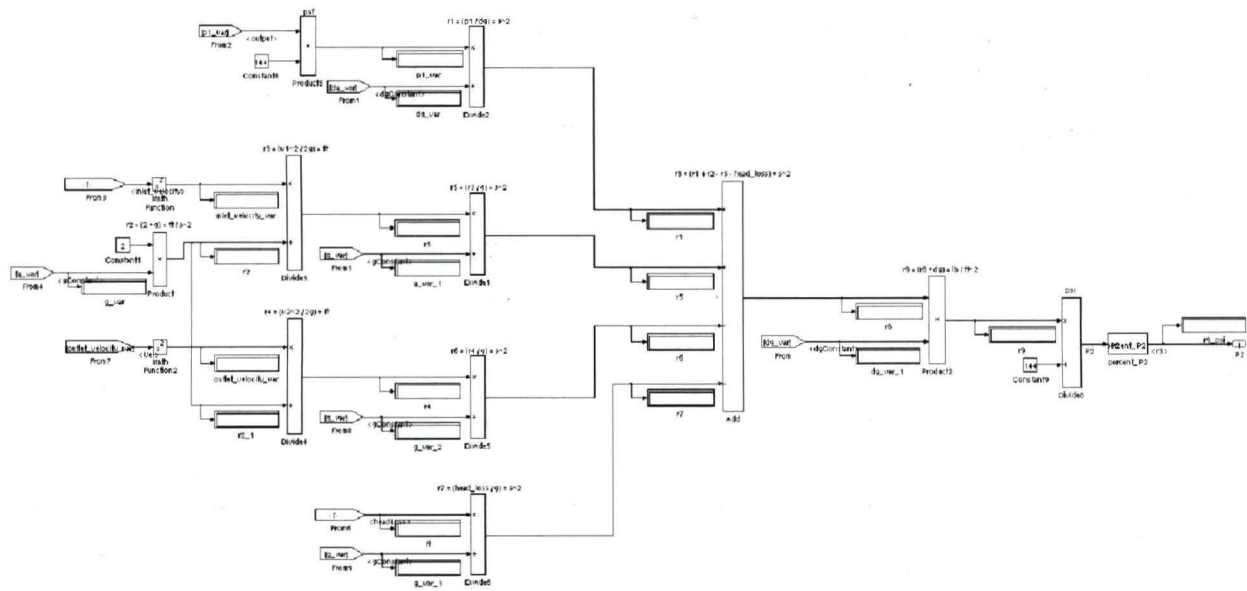


Figure 4. Pressure Differential inside Subsystem

C. Testing

After the dryer is modeled, it must go through a system test. The purpose of the test is to make sure the model performs the requirements correctly. I wrote the equations for the pressure and velocity differentials in Matlab. I created test variables to compare the Matlab code against the output of the model. I gave the test variables different values to ensure all possibilities were considered. I completed the model advisor after all iterations of my model passed. The model advisor checks for any possible modeling standard errors. The dryer model is promoted to the graphical user interface called AccuRev and awaits peer review for any corrections.

III. Conclusion

The assignment for the internship was both challenging and applicable to the field of engineering. I have learned the types of tasks involved on a daily basis. I gained valuable time management skills and industry training. This opportunity has enhanced my skill set to better prepare me for a career in engineering.

Acknowledgments

I would like to thank the KSC FO for funding and giving me the opportunity to undertake an engineering internship at NASA. I would like to thank my mentor Cheryle Mako and all management who took responsibility of me during my internship. Special thanks to Camiren Stewart and the simulation group for sharing their wealth of knowledge and valuable time, they have made my experience with NASA both enjoyable and valuable.

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